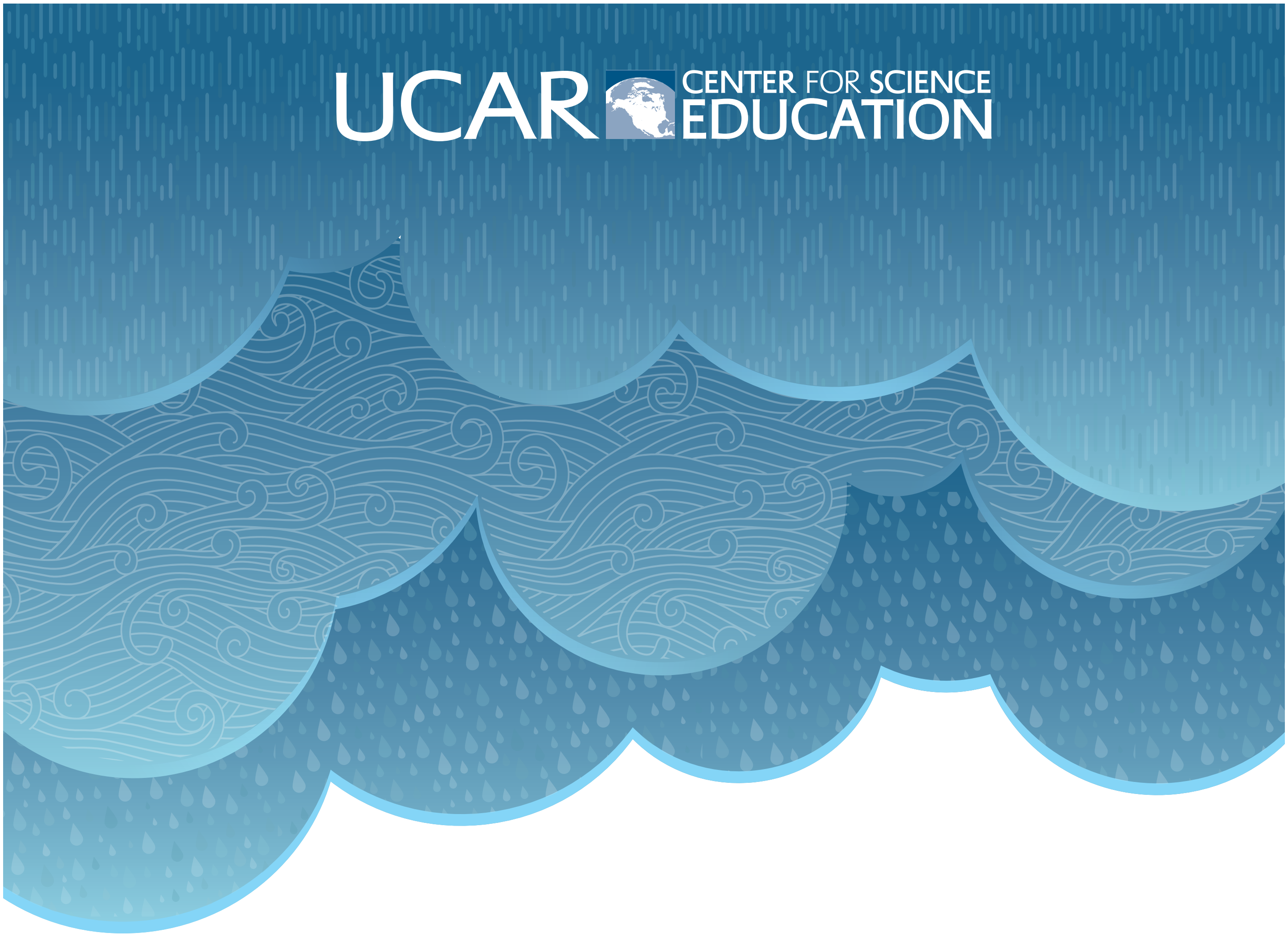

TEACHER GUIDE

THE GLOBE PROGRAM

BSCS SCIENCE LEARNING

NASA

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TEACHER GUIDE

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Overview of GLOBE Weather

With GLOBE Weather, middle school students explore phenomena related to weather and storms during a five-week unit to help them understand weather at local, regional, and global scales. They analyze weather data collected at schools that are a part of the GLOBE Program (www.globe.gov), and they make their own observations of weather following GLOBE Atmosphere Protocols.

Thunderstorm (Courtesy: Bob Henson, UCAR)

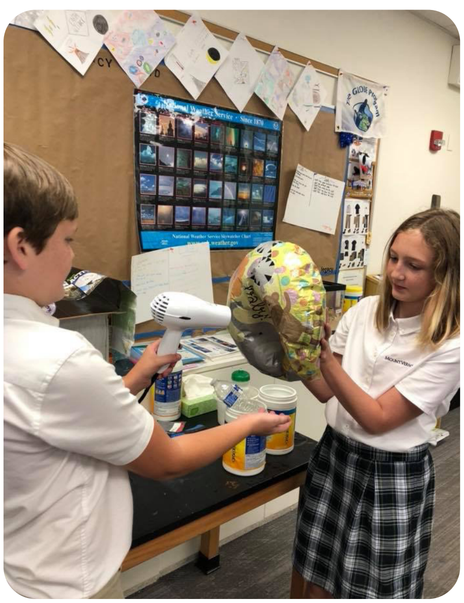
The GLOBE Weather curriculum has been developed to directly address Next Generation Science Standards focusing on student explorations of weather phenomena and utilizing a storyline approach within three 5E learning cycles (Bybee, et al., 2006). The curriculum has a particular focus on analysis and interpretation of weather data and iterative development of models to explain and document student understandings. Avenues for further explorations of weather with the GLOBE Program provide opportunities to extend student learning with research projects.

STORYLINE APPROACH

GLOBE Weather uses a storyline instructional approach to help sequence learning and flow logically for students from beginning to end. The intent of a storyline is to make the unit's lessons coherent from the student perspective. Students know what they are working on and why as they go through the unit. GLOBE Weather focuses on questions in each lesson, rather than topics, in order to provide students with motivation for each lesson and to keep the focus on exploration and discovery.

The instructional supports provided in the teacher instructions are intended to help you in make the storyline clear to students throughout the unit. The class as a whole develops ideas over time, motivated by questions about weather phenomena. Throughout the unit, the story of weather unfolds gradually. Individual lessons address a particular question and, over time, understanding builds. The storyline approach supports students' agency in sensemaking, allowing them to figure out science ideas and put them together over time.

A FOCUS ON WEATHER PHENOMENA



Students experiment with air temperature and movement during GLOBE Weather Lesson 5. (Courtesy: Susan Oltman)

Interesting phenomena are key to the storyline approach. It might be a surprising or puzzling phenomenon, something that students have come to accept but cannot explain, like clouds changing shape and size. It might be a phenomenon that students want to be able to predict and prepare for, like a violent storm. Or, it might be an everyday phenomenon that mystifies students when they stop to think about it, like why a small cloud spontaneously appears in a once completely clear sky.

In GLOBE Weather, phenomena are carefully selected to anchor a storyline. The *anchoring phenomenon* for this unit is a precipitation event in which an unusually large amount of precipitation happened in a relatively short amount of time in Colorado (U.S.), in September 2013. Students broaden from this storm event to consider many different types of precipitation events. They begin to ask why and how moisture moves in the air and when conditions are just right for rain or snow.

STUDENT EXPERIENCES WITH DATA ANALYSIS AND MODELING

In GLOBE Weather, science and engineering practices provide the means by which students advance through the storyline with a particular focus on data analysis and constructing models. They analyze weather data as a way of exploring storm phenomena, including analyzing graphed and mapped data of temperature, precipitation, humidity, and wind. The weather data in this curriculum was collected by GLOBE schools, CoCoRaHS (Community Collaborative Rain, Hail, and Snow) citizen scientists, and the National Oceanic and Atmospheric Administration (NOAA). Students construct models to organize their ideas and share their explanations of weather phenomena with others (see pages 14-15 for more information).

Raindrops (Courtesy: Carlye Calvin, UCAR)

OPTIONS TO EXTEND LEARNING THROUGH GLOBE INVESTIGATIONS

If you choose, we encourage you to have your students collect their own weather data using resources from the GLOBE Program or search for and analyze data collected by other students as a part of the GLOBE Program. This can allow students to conduct their own science investigations and make connections with students around the world. You will need to add time to the unit if you decide to do these optional GLOBE investigations (see pages 12-13 for more information).

WHAT YOU'LL FIND IN GLOBE WEATHER

With five weeks of instruction (approximately 25, 50-minute class periods), GLOBE Weather begins with an Anchor lesson and continues with three guided-inquiry Learning Sequences that explore weather phenomena at increasing spatial (local, regional, and global) and temporal (from short-lived to ongoing) scales. The Culminating Task provides an opportunity for students to apply what they have learned with a new, related phenomenon.

- **Anchor:** GLOBE Weather starts with an anchoring phenomenon: an extreme rainfall event that prompts students to question how and why storms happen and allows students to relate the storm profiled to their own experiences with storms.
- **Three Learning Sequences (LS):** Each Learning Sequence is designed to launch students into a modified 5E learning cycle (Engage, Explore, Explain, Elaborate). There are opportunities to evaluate student understanding along the way. At times, students are prompted to return and reconsider phenomena that they learned about before, such as the Anchor, as they figure out new science they can apply to it.
  - **Learning Sequence 1:** Students start with an investigation of short-lived, isolated storms, learning how they typically occur in the afternoon, the relationship between isolated storms and air temperature, and what determines whether growing clouds will cause precipitation.
  - **Learning Sequence 2:** Students progress to investigations of how air masses collide at fronts, which can cause stormy weather over a larger region and over many days, especially at cold fronts where a cold air mass pushes into a warm air mass.
  - **Learning Sequence 3:** Students zoom out to explore how and why storms move around the world due to atmospheric circulation caused by the uneven heating of the Earth.
- **Culminating Task:** Students investigate a winter storm, applying what they have learned through the curriculum based on their investigations of other types of storm phenomena.

See pages 6-11 for a summary of each lesson.

Next Generation Science Standards

PERFORMANCE EXPECTATIONS (PEs)

GLOBE Weather is aligned with three PEs. Note that the strike-through text below denotes concepts that are beyond the scope of this unit.

- **MS-ESS2-5:** Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
- **MS-ESS2-6 (partial):** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric ~~and oceanic~~ circulation ~~that determine regional climates.~~
- **MS-ESS2-4 (partial):** Develop a model to describe the cycling of water through Earth's systems driven by energy from the Sun ~~and the force of gravity~~.

DISCIPLINARY CORE IDEAS

GLOBE Weather combines content from five DCIs. Note that the strike-through text below denotes parts of DCIs that are not covered.

- **ESS2.C:** The complex patterns of the changes and the movement of water in the atmosphere, determined by wind, ~~landforms, and ocean temperatures and currents~~, are major determinants of local weather patterns. (MS-ESS2-5).
- **ESS2.C:** Water continually cycles among land, ocean, and atmosphere via ~~transpiration,~~ evaporation, condensation ~~and crystallization,~~ and precipitation, ~~as well as downhill flows on land~~. (MS-ESS2-4).
- **ESS2.C:** Global movement of water and its changes in form are propelled by sunlight ~~and gravity~~ (MS-ESS2-6).
- **ESS2.D:** Weather ~~and climate~~ are influenced by interactions involving sunlight, the ocean, the atmosphere, ~~ice, landforms, and living things~~. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect ~~oceanic and~~ atmospheric flow patterns. (MS-ESS2-6).
- **ESS2.D:** Because these patterns are so complex, weather can only be predicted probabilistically (MS-ESS2-5).

SCIENCE AND ENGINEERING PRACTICES (SEPs)

GLOBE Weather focuses on two SEPs: (1) developing and using models and (2) analyzing and interpreting data. Additionally, students gain experience with asking questions, carrying out investigations, constructing explanations, and obtaining, evaluating, and communicating information.

CROSSCUTTING CONCEPTS (CCCs)

GLOBE Weather includes three CCCs: (1) cause and effect, (2) systems and systems models, and (3) patterns.

Helpful Prior Knowledge

SCIENCE

Your students' prior learning of physical science concepts and water cycling can notably influence the implementation of the GLOBE Weather unit. While GLOBE Weather reiterates disciplinary concepts that are part of MS-ESS2-4 (water cycling), it is helpful for students to have met the performance expectation prior to GLOBE Weather. Parts of physical science Performance Expectations, particularly those related to DCI PS1.A (Structure and Properties of Matter) at the fifth grade and middle school levels, will also be relevant as you teach GLOBE Weather as students will use the understanding of molecules and how air with different properties interact. Additionally, throughout the unit pay attention to concepts that students may be readily using from previous grades.

MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the Sun and the force of gravity.

- ESS2.C. Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation, crystallization, and precipitation.

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.

- PS1.A. Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects.

3-ESS2-1. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.

- ESS2.D. Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next.

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

- PS1.A. Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- PS1.A. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- PS3.A. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

- PS1.A. Structure and Properties of Matter: Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) than can be used to identify it.

GEOGRAPHY

Students will explore weather data on maps in GLOBE Weather. At a regional scale, they will investigate weather fronts over the continental United States. At a global scale, they will investigate how temperatures vary with latitude and how storms move around the world. Thus, a basic understanding of maps and map keys is important as well as concepts such as latitude, the poles, the equator, and cardinal directions (North, South, East, West). Students may need support understanding the difference between a map view and a cross-sectional view.

National Geography Standard 1. How to use maps and other geographic representations, geospatial technologies, and spatial thinking to understand and communicate information.

GLOBE Weather: Lesson-by-lesson

	Lesson and question (time estimate)	What students do	What students learn
ANCHOR	**Lesson 1: An Unexpected Storm** *What do we know about storms?* **(100 MIN.)**	Watch a video about an extreme rainfall event and draw a description of what happened during the storm. Recall experiences with different kinds of storms.	• Extreme weather events like the Colorado storm impact our lives and communities. • Storms are a part of the water cycle.
LEARNING SEQUENCE 1: FROM CLOUD TO STORM	**Lesson 2: Watching the Sky** *What causes storms to form?* **(50 MIN. PLUS TIME FOR SKY WATCHING)**	Make weather observations from sunny and stormy day time-lapse videos. Make GLOBE cloud observations.	• Water vapor gets into the sky by evaporation. • Water evaporates when it's heated by the Sun. • Clouds form when water condenses.
LEARNING SEQUENCE 1: FROM CLOUD TO STORM	**Lesson 3: Temperature Clues** *How does temperature relate to cloud formation?* **(90 MIN.)**	Collect air temperature data from different altitudes in the troposphere using the online *Virtual Ballooning* interactive. Analyze temperature data collected at Westview Middle School, Longmont, CO. Optional: GLOBE temperature data collection and analysis.	• Air temperatures are warmer near Earth's surface and colder as you move higher in the troposphere. • During a sunny day, sunlight warms the ground, which heats the air just above the ground. • Clouds typically build in the afternoon once energy from the Sun has warmed the land surface, which has warmed the air above it.

LEARNING SEQUENCE 1: FROM CLOUD TO STORM	**Lesson 4: Fuel for Storms** *What is different about a warm, sunny day and a warm, stormy day?* **(80 MIN.)**	Compare weather data collected at a GLOBE school from a sunny day and a stormy day. Create and test models of sunny day conditions and stormy day conditions. Extension: Collect relative humidity and precipitation data following GLOBE Protocols to keep track of the weather.	• For a storm to form, moisture is needed. • Water vapor gets into the air from evaporation off the ocean, lakes, rivers, and from moisture in soil. • On days with low humidity, there isn't enough moisture for a storm.
	Lesson 5: Air on the Move *How does air move and change when a storm is forming?* **(100 MIN.)**	Experiment with how warm air rises and cooling air sinks using a Mylar balloon and hair dryer. Make a graphic model to explain how an isolated storm forms	• As air warms, molecules spread apart. Air becomes less dense and moves upward. • As the air at Earth's surface is heated from the Sun, it rises. • Higher in the atmosphere, the warm air cools and water vapor within it condenses, forming clouds and possibly a small storm called an isolated storm. • When air cools, molecules become closer together. Air becomes denser and sinks to the Earth surface. • The pattern of rising and sinking air is called convection.
	Lesson 6: Making a Thunderstorm *Can we identify the best conditions for storms?* **(50 MIN.)**	Test what temperature and humidity conditions will lead to a storm using the online *Make a Thunderstorm* interactive and graphic models developed during Learning Sequence 1.	• Changes in temperature or relative humidity will affect whether an isolated storm will happen and how big the storm might be. • A strong isolated storm is most likely to happen when there are warm temperatures near the ground, much colder temperatures higher up, and high humidity.

LEARNING SEQUENCE 2: A FRONT HEADED YOUR WAY	7 **Lesson 7:** **A Different Kind of Storm** *What other types of storms cause precipitation?* **(30 MIN.)**	Make weather observations from a time-lapse video of a cold front storm. Analyze a weather forecast for a week when a cold front came through a location.	• A cold front storm lasts longer than an isolated storm, and there is a dramatic change in the temperature and moisture in the air before and after the storm.
	8 **Lesson 8:** **Weather Before, During, and After a Cold Front** *How is air changing before, during, and after a cold front?* **(50 MIN.)**	Students analyze air temperature, humidity, and wind data collected by a GLOBE school before, during, and after a cold front.	• The air before a cold front is warmer with higher humidity. • During a cold front, temperature drops and it rains. • After a cold front, temperatures are cooler and the air is less humid.
	9 **Lesson 9:** **Storms and Precipitation Along a Front** *What causes precipitation along a cold front?* **(100 MIN.)**	Students make observations and draw a model of what happens in a density tank when warm water (simulating a warm air mass) and cold water (simulating a cold air mass) meet to understand what happens at a cold front. Students create a map of temperature and precipitation data and determine the location of the cold and warm air masses and the front between them.	• When a cold air mass moves into a warm air mass, the warm air is pushed upward. • The warm air cools when it is pushed upward, causing water vapor to condense, and precipitation may occur.

LEARNING SEQUENCE 2: A FRONT HEADED YOUR WAY	LESSON 10 **Lesson 10: Front on the Move** *What causes fronts to move?* **(100 MIN.)**	Students explore air pressure and how air moving downward at areas of high pressure spreads outward at the ground level. Analyzing a map of air pressure data in the Midwest, students determine the direction that the front is moving. Analyzing air pressure data from a GLOBE school, students explain how air pressure relates to cold fronts. Extension: Collect barometric pressure data following GLOBE Protocols.	• Areas of high pressure are usually behind a cold front, pushing the cold air mass into the warm air mass. • Air pressure is lower where air is rising at the front. • After a cold front, a location may experience high pressure associated with cooler, sinking air that has less moisture.
	LESSON 11 **Lesson 11: A Closer Look at Low-Pressure Systems** *What could cause a front to stall?* **(75 MIN.)**	Re-watch a video of the Boulder, CO flood from 2013. Examine Boulder, CO storm data from September 2013.	• Rainfall totals for the Colorado storm were high because it stalled, causing lots of rain to fall in the same place. • The storm didn't move because it was surrounded by areas of high pressure. • The storm was very moist because low pressure was pulling in humidity evaporated from both the Gulf of Mexico and the Pacific Ocean.

LEARNING SEQUENCE 3: WORLDWIDE WEATHER

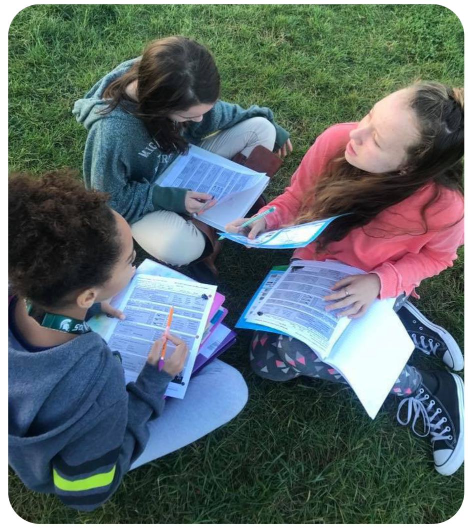
12 **Lesson 12: Storms on the Move** *How do storms move around the world?* **(50 MIN.)**	Students make observations of time-lapse satellite videos that show storm movement.	• There is a predictable pattern of storm movement that correlates with latitude. • In North America and in other midlatitude areas, storms generally move from west to east.
13 **Lesson 13: Heating Up** *Why is it hotter at the equator than other places on Earth?* **(90 MIN.)**	 Students explore why it's hotter near the equator than near the poles by interpreting GLOBE temperature data from different latitudes.	• Incoming sunlight hits the equator directly, concentrating it in a smaller area than at higher latitudes. • More-concentrated solar radiation causes higher air temperatures near the equator than at higher latitudes.
14 **Lesson 14: Air Movement in the Tropics** *How and why does air move in the tropics?* **(90 MIN.)**	Students use a model to investigate how air moves in large-scale convection from the equator to 30° north and south of the equator. They apply what they learned about small-scale convection to a larger scale to understand where clouds are likely to form and make a model of global convection.	• Convection happens on a large scale as warm air rises at the equator, cools, and then sinks at 30°N and 30°S. • There is low pressure at the equator because warm air is rising. • Because air is rising, cloud formation is common at the equator. • There is high pressure at 30°N and 30°S where air is sinking. • Because air is sinking, clear skies are common at 30°N and 30°S. • The rising and sinking air causes air at the Earth's surface in the tropics to move towards the equator.
15 **Lesson 15: A Curveball** *When air and storms move, why do they curve?* **(55 MIN.)**	Students find evidence that their convection model doesn't explain the pattern by which storms move that they observed in Lesson 12. They read about the Coriolis effect and use a simple model to simulate how Earth's rotation changes the direction of prevailing winds in the tropics.	• While we'd expect air to move directly towards the equator in the tropics, it actually is curved due to Earth's rotation so that, in the northern hemisphere, tropical air moves from northeast to southwest rather than north to south. • In the midlatitudes, air moves mostly west to east due to Earth's rotation.

CULMINATING TASK	CULMINATING TASK: **Challenge 1** **Challenge 1: California Storm** **(50 MIN.)**	Students use what they have learned in GLOBE Weather to explain precipitation patterns and the direction of movement for a winter storm that arrived on the U.S. West Coast on February 21, 2017.	• Because air temperature decreases with altitude in the troposphere (LS1) the storm could bring snow to high elevations and rain to low elevations in the Sierra Nevada. • The storm's moisture most likely comes from evaporation off the Pacific Ocean (LS1). • Because storms generally move from west to east in the midlatitudes, due to prevailing winds (LS3), this storm is heading across the U.S.
	CULMINATING TASK: **Challenge 2** **Challenge 2: Where's the Snow?** **(50 MIN.)**	Students analyze maps of snowfall and humidity data in the Rocky Mountains and Southwest for February 23, 2017.	• Snow fell near the area of low pressure on the northern end of the cold front (LS2). • The humidity was low at the southern end of the cold front, which explains why there was no precipitation (LS1).
	CULMINATING TASK: **Challenge 3** **Challenge 3: We're Warning You** **(50 MIN.)**	Will there be a snow day? Students predict which Midwest locations are likely to get enough snow from the winter storm that they will need to close for the day.	• Predicting where the heaviest snow will fall on February 24 takes into account where it snowed along the front on February 23 (LS2). • The forecast, weather watches and warnings, and whether the community is prepared to deal with snow and ice will determine school closures.

Connection with the GLOBE Program

Major funding for the GLOBE Program and GLOBE Weather comes from the National Aeronautics and Space Administration (NASA). The purpose of GLOBE Weather is 1) to produce resource to meet a national need for K-12 science and 2) to introduce teachers and students to the GLOBE Program. A recommendation of a board of advisors during a review of the GLOBE Program in June 2016 stated the following, which led to the development of GLOBE Weather:

> **"At this moment, U.S. STEM education is under significant pressure to change: new standards such as the Next Generation Science Standards, Common Core, and state-led initiatives increase the visibility and emphasis on inquiry science, Earth and geosciences, and citizen science in K-12 classrooms across the 50 states and other U.S. jurisdictions. GLOBE could play a vital role in these changes ... The GIO [GLOBE Implementation Office] should consider strategies for new initiatives that will increase the use and impact of GLOBE in the U.S. ... to develop and pilot innovative materials for instruction and professional development."**



Making cloud observations using the GLOBE Cloud Protocol (Courtesy: Susan Oltman)

Teachers and students can be introduced to the GLOBE Program through the resources (i.e., science protocols and science data) that have been developed over the 20+ years of the program and are embedded into the unit. GLOBE Weather provides avenues and opportunities for teachers interested in this new way of teaching weather, driven by performance expectations in the Next Generation Science Standards (NGSS Lead States, 2013).

COLLECTING WEATHER DATA USING GLOBE PROTOCOLS

In the unit itself there are implicit opportunities for students to use GLOBE science protocols (i.e., air temperature, surface temperature, clouds, and precipitation) to collect environmental data that can be used to make sense of fundamental concepts (e.g., how solar radiation affects the temperature of Earth's surface and the air near the ground, how the types of clouds can indicate the type of weather). Using GLOBE protocols will provide opportunities for students to collect authentic data from their local environment, enhancing understanding of concepts related to clouds and air temperature patterns, while encouraging the use of instruments to collect surface and air temperature. This directly aligns with the *Planning and Carrying Out Investigations* Science and Engineering Practices from NGSS.

Science protocols related to the GLOBE Weather curriculum can be accessed in the Atmosphere section of the GLOBE Program website: globe.gov/do-globe/globe-teachers-guide/atmosphere

ANALYZING GLOBE WEATHER DATA

Explorations of GLOBE data will lead to a more sophisticated understanding of "how the motions and complex interactions of air masses result in changes in weather conditions" and how to "develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates" (from NGSS Performance Expectations MS-ESS2-5 and MS-ESS2-6). By engaging students directly with the GLOBE Weather materials, teachers use GLOBE resources in their classrooms, benefitting learners.

STUDENT RESEARCH PROJECTS

There are also explicit connections for teachers to provide students with more opportunities to conduct investigations. For each learning sequence, we have developed GLOBE Connections that include ideas for using the lessons as a jumping-off point for student research and environmental explorations that use GLOBE protocols, use the GLOBE Visualization Tool, or connect with GLOBE schools from around the world. GLOBE Connections are available on the GLOBE Weather website (globeweathercurriculum.org).

- In Learning Sequence 1 (From Cloud to Storm), the GLOBE Connection *From Observation to Investigation* has students using their observations and data collected using science protocols to form testable questions for independent or small-group investigations.
- In Learning Sequence 2 (A Front Headed Your Way), students analyze GLOBE data from Freedom High School in Virginia to better understand the movement of a cold front and its associated storms. In the GLOBE Connection *Finding Freedom*, students use the GLOBE Visualization Tool to find the data from Freedom High School and then use the tool to look for other patterns in temperature, humidity, and pressure data that could indicate a cold front in a different part of the United States.
- In Learning Sequence 3 (Worldwide Weather), the GLOBE Connection *GLOBE Schools around the World* introduces students to the international community that makes GLOBE unique. Students are provided with the opportunity to interact with students in GLOBE schools to discuss the question: “Are there regular patterns of storm movement in other parts of the world?”

Students measuring surface temperature using an IR thermometer (Courtesy: Susan Oltman)

Thunderstorms (Courtesy: Carlyle Calvin)

These investigations could be part of students’ research projects for local science fairs or for submission to the regional GLOBE Student Research Symposium (globe.gov/science-symposium), the annual GLOBE International Virtual Science Symposium (IVSS) (GLOBE, 2019), or published in the student research repository on the GLOBE website. For the IVSS, students are also encouraged to look at ways to improve their local environments.

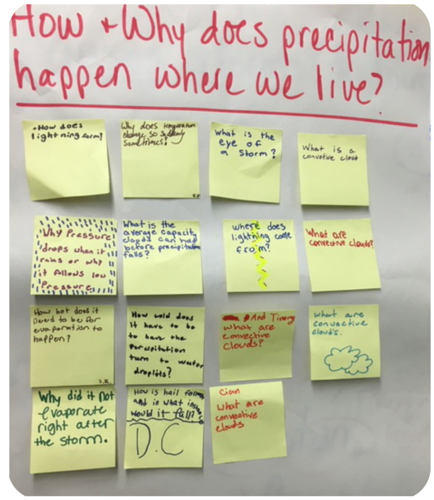
As described above, there are many ways for teachers and students to become more involved with the GLOBE Program and at the same time improve their instruction and student learning at the middle school level. The program makes a positive difference in people’s lives and benefits the environment.

GLOBE Weather Instructional Routines

Throughout the GLOBE Weather unit, you'll notice a few instructional routines used to support NGSS-based science instruction. These routines underpin much of the sensemaking work your students will engage in as they ask questions about and investigate phenomena to figure something out.

THE DRIVING QUESTION BOARD

As part of GLOBE Weather's storyline approach, students articulate questions to define what they need to learn about storms and weather. They document their questions on a Driving Question Board, a tool to generate, keep track of, and revisit student questions related to weather phenomena that students are exploring. The Driving Question Board is a visual representation of the questions generated by the class and is displayed in the classroom during the unit. A Driving Question Board can be constructed with sticky notes or sentence strips, written on whiteboards, or made with shared software applications.



Example of a GLOBE Weather Driving Question Board (Courtesy: Denise Magrini)

The Driving Question Board is introduced at the beginning of the unit and then revisited periodically. It serves as a record of students' curiosities about phenomena and a way of documenting the progress that they make in understanding the phenomena under study. It is important that students understand there will be more questions on the Driving Question Board than can be answered during the unit.

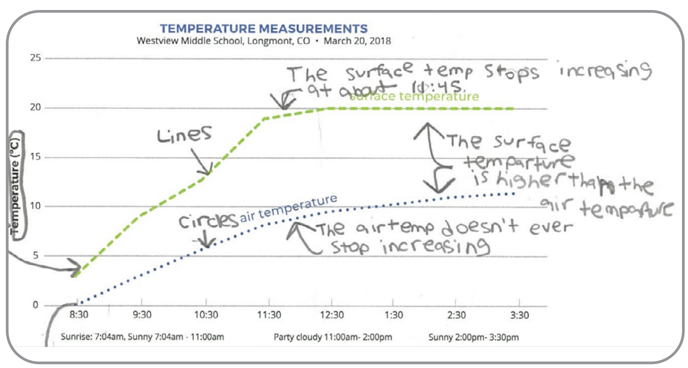
To prepare a paper version of the Driving Question Board:

- Write a question on a sheet of poster board or chart paper (see the sample questions in the table on page 16).
- Make a space in the classroom for the Driving Question Board that is easily accessible to students.
- Provide sticky notes and markers that students will use to document their questions.

ANALYZING WEATHER DATA

The Identify and Interpret (I²) Sensemaking Strategy, developed by BSCS, is a way to help students who need support with interpreting graphed data. In GLOBE Weather, the I² Sensemaking Strategy is embedded within data analysis activity sheets to help students make connections between graphical weather data and their ideas about the science of weather.

The I² Sensemaking Strategy makes sense of graphed data by breaking it down into smaller parts.



Example of a student's data analysis.

1. Students make observations of the data. They draw an arrow to each observation and then write a What I See statement to describe it.
2. Students write a What it Means statement for each WIS statement. Often, a "What it Means" statement could be more accurately called "What I Think it Means." Encourage students to write these statements to reflect what they think the data is showing, even if they are not completely certain.
3. Students create a caption for the graph that summarizes the information and document what they have learned.

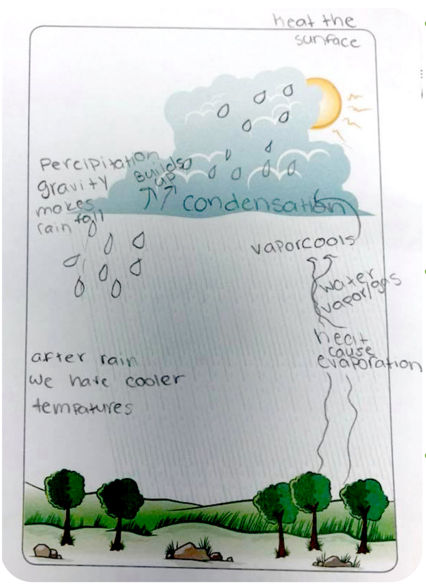
When you first use this strategy, model it for students by completing an I² Sensemaking Strategy on a graph in front of the class while articulating your thought process. Students may need support to understand what they should be looking for on a graph. Help students hone their observations so that they focus on the parts of the data that can help them answer the question they are investigating.

STUDENT-DEVELOPED MODELS

A model is an abstract representation of a phenomenon that is used as a tool to explain how or why something in the world works the way it does (McNeill, Katsh-Singer, & Pelletier, 2015; National Research Council, 2013). Scientific models are sensemaking tools that help us to predict and explain the world, while engineering models are used for analyzing, testing, and designing solutions (Passmore, Schwarz, & Mankowski, 2017). In general, models can be represented as diagrams, 3-D objects, mathematical representations, analogies, or computer simulations (National Research Council, 2013).

Students work together to build consensus models throughout GLOBE Weather. (Courtesy: Susan Oltman)

Developing models is the central activity in GLOBE Weather. Students build conceptual understanding of science by creating and revising models to explain weather phenomena. In GLOBE Weather, students develop models to support their own sensemaking and to help them visually articulate their ideas about atmospheric processes. The models that students develop throughout the unit can be used to track learning progress over time. Below are descriptions of the three types of models that students develop in GLOBE Weather:



Example of a student's working model from GLOBE Weather. (Courtesy: Susan Oltman)

- **Working Models:** In each Learning Sequence, students develop Working Models to explain aspects of the phenomenon under investigation. Working Models are a place where students can represent their initial thinking, new ideas, or revised ideas in a low-stakes environment. Working Models can be developed individually or in small groups and then used as a way to share ideas with the class. Working Models are like pieces of the larger puzzle that are put together when the class creates a Consensus Model.
- **Model Ideas and Model Idea Tracker:** Periodically within the unit, students take stock of new Model Ideas—rules that govern how weather works, which students figure out through investigation. The Model Ideas the whole class agrees upon are documented in the class Model Idea Tracker, a piece of chart paper kept in a space in the classroom that students can easily reference.
- **Consensus Models:** In each learning sequence, the class collectively develops a Consensus Model drawing from the Model Ideas in the Model Idea Tracker and the Working Models students have developed to record their own explanation of the learning sequence phenomenon. The Consensus Model is a visual representation that the class agrees will help them explain the learning sequence phenomenon. Students have opportunities to test each Consensus Model, identify its limitations, and add new ideas to it.

The models that students develop are helpful tools for explaining what's happening in the system; however, like all models, they will be imperfect in that they will simplify aspects of atmospheric science. The atmosphere is more complex and chaotic than students will represent in their models, yet student-produced models will represent the primary factors that affect weather, such as changes in temperature and moisture.

How Phenomena Relate to Student Questions and Sample Model Ideas for each GLOBE Weather Learning Sequence

	Learning Sequence 1: From Cloud to Storm	**Learning Sequence 2: A Front Headed Your Way**	**Learning Sequence 3: Worldwide Weather**
Investigative Phenomenon	Clouds can grow during a day and turn into an isolated storm.	Storms forms where different air masses are in contact at fronts. At a cold front, a cold air mass is pushing into a warm air mass.	Precipitation moves from east to west near the equator.
Student Question	*What causes an isolated storm?*	*What other types of storms cause precipitation?*	*Why do storms move in predictable patterns around the world?*
Sample Model Ideas	• Evaporation of water from Earth's surface is important for clouds/storms to form. • Evaporation happens because of heating of the surface from sunlight. • Clouds form when water condenses. • The surface is warmer than the air above it. • The air near the ground is warmer than air near where clouds form. • Rising temperature and humidity are good conditions for an isolated storm. • Rising temperature and low humidity are not good conditions for an isolated storm. • A source of moisture is important to get water into the atmosphere for storms. • Warm air rises and cooler air sinks. • Warm air can hold more water vapor than cool air.	• When cold air meets warm air, the cold air goes below the warm air. The warm air goes up into the atmosphere. • Air masses can have different temperatures and amounts of moisture. • If a warm, moist air mass is pushed upward, some water vapor will condense into clouds, which can lead to precipitation. • An area of high pressure is usually behind a cold front. • An area of low pressure is typically at the front/northern end of a cold front (in the northern hemisphere). • After a cold front, a location may experience high pressure associated with cooler, sinking air that has less moisture. • Just before and during the storm, an area may experience low pressure, which is associated with warm, rising air and precipitation. • Air moves from high to low pressure. **Colorado 2013 storm-specific model ideas:** • Three areas of high pressure trapped the front and it stalled. • The low pressure wasn't moving either and kept pulling in moisture from the Gulf of Mexico and the Pacific Ocean.	• As warm air rises at the equator, it creates an area of low pressure. • Sunlight (solar radiation) is more concentrated at the equator because incoming sunlight shines directly on the equator, concentrating it in a smaller area. • Sunlight (solar radiation) is more spread out toward the poles because incoming sunlight hits the surface at an angle, spreading the light out over a larger area. • The amount of concentrated solar radiation influences air temperatures; more-concentrated solar radiation causes higher air temperatures, and solar radiation that's more spread out causes cooler air temperatures. • Larger pockets of warm air rise near the equator, and pockets of cool air sink at 30°N and 30°S. • Cooler air moves along the surface of Earth toward the area of low pressure to replace the rising warm air. • Horizontal movement of air along the surface of Earth is wind, which causes precipitation to move.

Supplies You'll Need

Below is an overview of the supplies that you will need to implement GLOBE Weather in your classroom. A detailed supply list that includes quantities is provided with the instructions for each lesson.

TECHNOLOGY

- Weather videos streamed online and projected for the class (Video URLs are in lesson instructions.)
- Computers or tablets for students use
- Tablets or smartphones (optional)
- *UCAR Field Guide to Clouds* app (optional)
- *GLOBE Observer* mobile app on tablets or smartphones (optional)

SUPPLIES FOR THE DRIVING QUESTION BOARD, MODEL IDEA TRACKER, AND CONSENSUS MODELS

- Chart paper
- Sticky notes
- Markers

HANDOUTS

- Student Activity Sheets for each lesson
- Assessments for each Learning Sequence
- GLOBE Weather Final Assessment

HANDS-ON ACTIVITY AND DEMONSTRATION SUPPLIES

- Latex balloons
- Lentils
- Markers
- Colored pencils
- Cloud identification charts or apps
- 100-watt incandescent bulb and lamp (e.g., clamp lamp)
- Clear plastic soda bottles
- Thermometers
- Funnel
- Sand or soil
- Water
- Rubber stoppers
- Mylar balloon filled with helium
- Hairdryer
- Drinking straw
- Density tank with divider and petroleum jelly
- Electric kettle or other means of heating water
- Ice cubes
- Red and blue food coloring
- Inflatable globe
- Clipboards
- Rulers
- Flashlights
- Graph paper
- Clear plastic tub
- Pipettes
- Sturdy cups, such as ceramic mugs
- Temperature and latitude cards (printed from Learning Sequence 3)
- Tablets or smartphone for taking photos, time-lapse videos, and slow-motion videos (optional)

GLOBE PROTOCOLS

(Note: All are optional extensions except for the cloud protocol.)

- Cloud
  - Cloud and contrail chart
- Air Temperature
  - Min/Max thermometer
  - Calibration thermometer
  - Instrument shelter
- Surface Temperature
  - Infrared thermometer
- Relative Humidity
  - Digital hygrometer or sling psychrometer
- Barometric Pressure
  - Aneroid barometer
  - Altimeter
- Precipitation
  - Rain gauge

(Detail about specific equipment needed for GLOBE Protocols can be found at: globe.gov/do-globe/research-resources/globe-equipment/atmosphere)

Navigating the GLOBE Weather Curriculum

Icons within the teacher instructions highlight features of the curriculum, opportunities to deepen student understanding, literacy connections, assessments, and how GLOBE Weather aligns with the Next Generation Science Standards (NGSS). When you see one of these icons, consider what support your students might need and how you can modify instruction to meet those needs.

TEACHER ICONS

Disciplinary Core Ideas: highlights places where you elicit student understanding of core ideas or specify which core idea students are figuring out. Because many activities focus on developing core ideas, this icon is used to highlight core ideas that may need additional attention.

Crosscutting Concepts: highlights the specific concept students are working on and provides additional instructional guidance.

Scientific and Engineering Practices: calls out the specific practice students are engaged with and provides additional guidance on how to facilitate student participation in that practice.

Storyline Link: at the start, middle, and end of each lesson, highlights how to guide students so they experience the unit as a coherent storyline in which each activity has a purpose and is connected to what has gone before and what is coming next.

NGSS Sensemaking: describes the three-dimensional sensemaking students engage with and specifies which practices students engage with to figure out specific core ideas and crosscutting concepts.

Home Learning: provides suggestions for possible home learning assignments.

Literacy Connection: highlights activities that support literacy, such as reading expository text.

GLOBE Connection: indicates times when students collect or analyze GLOBE data.

Dig Deeper: notes suggestion for how to have students explore a topic in more depth if time allows.

Assessment: indicates opportunities to assess student understanding throughout the curriculum.

STUDENT ICONS

The following icons are used on the Student Activity Sheets and indicate the type of activity the students are working on.

What I See (WIS)

What It Means (WIM)

Download File/Application

Play a Video

Work Alone

Work in a Group

Stop and Think

Stop and Do

GLOBE Weather Assessment Resources

EMBEDDED PRE-ASSESSMENT

Lesson 1 of GLOBE Weather provides two opportunities for embedded pre-assessment that can illuminate student thinking and prior knowledge about the connection between the water cycle and weather. In Lesson 1, students are prompted to think, write, and draw to explain what they know about the water cycle, how storms form, and what happened in the Colorado storm example.

In their written answers, look for:

- words and scientific terms they use (e.g., evaporation, precipitation, and condensation) or expression of those ideas without using the terms.
- whether their story focuses mostly on water moving places or whether they also include sunlight, heat, temperature, or other references to energy.

In their drawing, look for:

- the processes students include in their diagrams (e.g., evaporation, condensation, precipitation).
- whether they represent water molecules or represent water on a larger scale.
- whether they include sunlight, heat, or energy as a mechanism for moving water around.

FORMATIVE ASSESSMENT

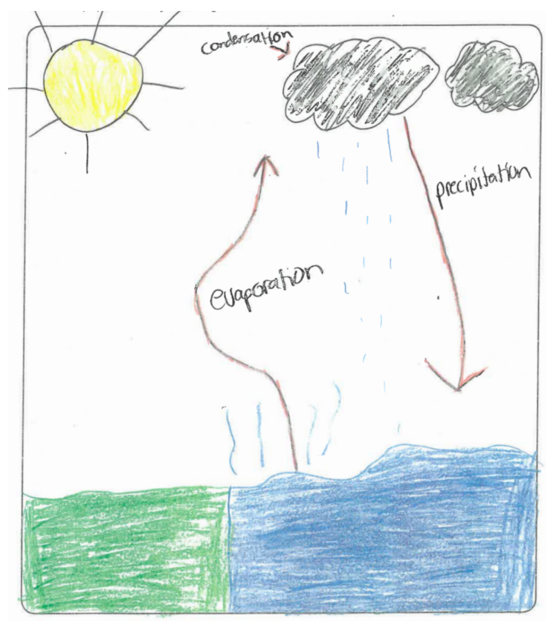
Each lesson includes a variety of opportunities for formative assessment that correspond to particular parts of student activity sheets and classroom discussions about the models that students are developing and the evidence to support the models. Formative assessment within each learning sequence includes the guiding question for the lesson and descriptions of opportunities to formatively assess students tied to the teacher instructions with exit ticket suggestions (see assessment pages 2-6).

LEARNING SEQUENCE SUMMATIVE ASSESSMENTS

Each learning sequence has a corresponding summative assessment. The items are open response and prompt students to use their knowledge of disciplinary core ideas and crosscutting concepts and engage in science practices (data analysis and modeling). Interpretive answer keys allow you to make sense of student learning and identify productive thinking and incomplete or inaccurate ideas.

FINAL ASSESSMENT

The final assessment is a ten item open response test that targets fundamental science ideas learned in the unit as well as the NGSS science practices of data analysis and interpretation and modeling. The assessment also prompts students to share what they know about the NGSS crosscutting concepts of patterns and cause and effect. The final assessment should be administered following the culminating task.



Sample of Lesson 1 pre-assessment student drawing

References

Bybee, R.W., et al. (2006) *The BSCS 5E Instructional Model: Origins and Effectiveness*, a Report Prepared for the Institute of Science Education, National Institutes of Health, downloaded from: bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model-Full_Report.pdf

GLOBE (2019) *GLOBE International Virtual Science Symposium*, downloaded from: globe.gov/news-events/globe-events/virtual-conferences

McNeill, K. L., Katsh-Singer, R., & Pelletier, P. (2015). Assessing science practices: Moving your class along a continuum. Science Scope, 39(4), 21-28.

National Research Council. (2013). *Next Generation Science Standards*: For States, By States. Washington, DC: The National Academies Press.

Passmore, C., Schwarz, C., & Mankowski, J. (2017). Developing and Using Models. In C. Schwarz, C. Passmore, & B. Reiser (Eds.), *Helping Students Make Sense of the World Using Next Generation Science and Engineering Practices*. Arlington, VA: NSTA Press.

Umbrellas (Courtesy: Carlye Calvin)